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EFFECTIVENESS OF A HIDROSTAL PUMP AND TRANSPORT SYSTEM IN THE LIVE TRANSFER OF FISH

Report No 82-295-K

P.H. Patrick
Biologist
Biological Research Section
Chemical Research Department

ABSTRACT

The effectiveness of the Hidrostal pump and transport system in the live transfer of fish was evaluated in the laboratory. Rainbow trout, smelt, alewife and yellow perch were successfully transported through the pump with minimal damage. Fish survival varied with pump speed (436 to 1163 rpm), and generally increased with a decrease in pumping speed. No significant increase in mortality occurred for fish transported through two different pipe loop systems over a 48-h period. For all species tested there was no relationship found between fish length and mortality or minor injury over the size ranges tested. A pumping speed between 436 and 604 rpm is recommended in the field design for optimal fish survival.

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To Dr. C.D. Burnham
Section Head
Environmental Sciences and Technology
Environmental Studies and Assessments
Design and Development

EFFECTIVENESS OF A HIDROSTAL PUMP AND TRANSPORT SYSTEM IN THE LIVE TRANSFER OF FISH

1. INTRODUCTION

As part of the Capitalized Once-Through Cooling (C.O.T.C.) 1981 program, Environmental Studies and Assessment requested the Biological Research Section to study the live transfer of fish through a pump and pipe return system. A review by Christie (1978) on fish pumps and extractors suggested that a screw-type impeller pump such as the 'Hidrostal' may show merit for use at Ontario Hydro's generating stations. This pump was initially developed for the commercial fishing industry where large volumes of fish must be handled with minimal or no damage. Since no measurement of fish survival following pump passage had been conducted, the suitability of this pump for live fish transfer was largely unknown. Recently, this pump has proved successful for passing larval fish (Holsapple, et al, 1981), and is currently being evaluated at two U.S. installations (Holsapple, pers comm). The objective of the present study is to evaluate the effectiveness of the Hidrostal pump and a pipe loop transport system in the live transfer of juvenile and adult fish, using species impinged at Ontario Hydro's generating stations.

2. MATERIALS AND METHODS

2.1 Fish Species Tested

Investigations were conducted using mainly rainbow trout, smelt, alewife and yellow perch, with brown bullhead, white suckers and juvenile gizzard shad being used in limited testing. These species represented both pelagic and benthic types over a wide range of sizes, and were collected at several locations (Table I).

TABLE I

SUMMARY OF FISH SPECIES USED IN HIDROSTAL PUMP TESTS

Species	Size Total length (cm)	Behaviour	Location collected	Gear Type
Alewife	10-16	pelagic	Pickering GS	seine
Smelt	8-12	pelagic	Pickering GS	seine
Rainbow trout	12-20	mid-depth	laboratory reared	--
Yellow perch	10-20	benthic-pelagic	Orangeville reservoir	trap net
Brown bullhead	19-28	benthic	Bruce GS	trap net
White suckers	16-40	benthic	Bruce GS	trap net
Juvenile gizzard shad	9-18	pelagic	Nanticoke GS	dip net

Rainbow trout, which were laboratory reared, were especially robust and highest survival following pump passage was expected for this species. Alewife and smelt are the dominant species impinged at most Ontario Hydro Generation Stations, and are highly susceptible to handling (induced mortality). It was reasoned that if these species, especially adult alewife, were able to pass unharmed through the pump system, other impinged species should have little or no difficulty. Both species were collected by seine net at night during the spring and summer at Pickering GS (Table I). Yellow perch represented a species whose viability was assumed to be intermediate between rainbow trout and alewife, and were collected by trap net at the Orangeville Reservoir.

All species were held in 3.6 m circular pools under a controlled natural photoperiod (10 to 14 h of light) prior to testing. During the rainbow trout tests, water temperatures in the experimental and holding tanks ranged from approximately 9.5 to 12°C. In experiments conducted with the other species, water temperatures were slightly higher (10 to 14°C). Rainbow trout were fed commercial 'trout' pellets, whereas yellow perch were maintained on earthworms. No attempt was made to feed alewife, smelt or the other test species. Fish condition prior to pumping was generally good, although there were exceptions. Alewife used in the short loop, low pump speed tests (436 rpm test, page 20) were noted to be in poor general condition. Smelt used in some of the long loop passage tests (604 rpm test, page 25) were observed to have a relatively high fungal

infection. All rainbow trout used in pump tests had some scale loss which was attributed to handling in the C.O.T.C. louvre study.

2.2 Hidrostal Pump

The Hidrostal pump (Model H5) used in this investigation is approximately half the diameter of the model proposed for installation at various Ontario Hydro Generating sites such as Thunder Bay TGS.

The unit has an enclosed screw-type impeller with three turns on the impeller blade, which allows passage of objects less than or equal to 7.6 cm in diameter. The pump was operated by a 10 hp (240 V) motor with a variable speed drive control that provided impeller speeds from 400 to 1200 rpm.

Experiments were conducted in a large concrete tank (12.2 m x 7.3 m), the construction of which is detailed in Ontario Hydro Research Division Report C81-26-K. The Hidrostal pump was mounted on a divider wall separating the tank into two equal areas. The intake was located in one half while water was discharged into the adjacent section (Figure 1). The intake and discharge pipes were approximately 25.4 cm in diameter, which resulted in water velocities in excess of 0.5 m/s in the transport system. Two transfer systems were designed, involving both a direct transfer (short loop), and transport through a long loop. The short loop system consisted of one 45° elbow (bend), and was approximately 2.1 m in length from the pump to discharge (Figure 1). The long loop was approximately 15.5 m in length and included two 45° and two 90° elbows (bends). The long loop system also included a transparent (acrylic) 1.0 m section immediately following the first 90° bend, and allowed viewing of fish as they were transported through the loop.

To introduce fish in the pump, a screened cage (approximately 2 cm mesh) was placed at the intake entrance (Figure 2). This cage was necessary since fish actively avoided the intake mouth. Still, fish in the screened cage area had to be diverted towards the pump. Strobe lights (OHRDR 81-190-K) and nets (physically moving fish) were successful in forcing fish into the Hidrostal pump. A more detailed discussion of fish avoidance of the intake area is given in the Results Section. Fish holding areas for both control and experimental groups of fish were located at the intake and discharge sections, respectively, of the tank (Figure 1).

Current velocities were estimated near the intake mouth at various pump speeds (436, 944, 1163 rpm) using an O.T.T. meter (OHRDR 80-238-K). Measurements of cross-sectional flow of the return pipe were estimated using a pitot-static tube (OHRDR 79-362-K) with a water manometer (calibrated for direct readout in cm/s). In the short loop transport, readings were made just below the 45° elbow of the discharge pipe, whereas

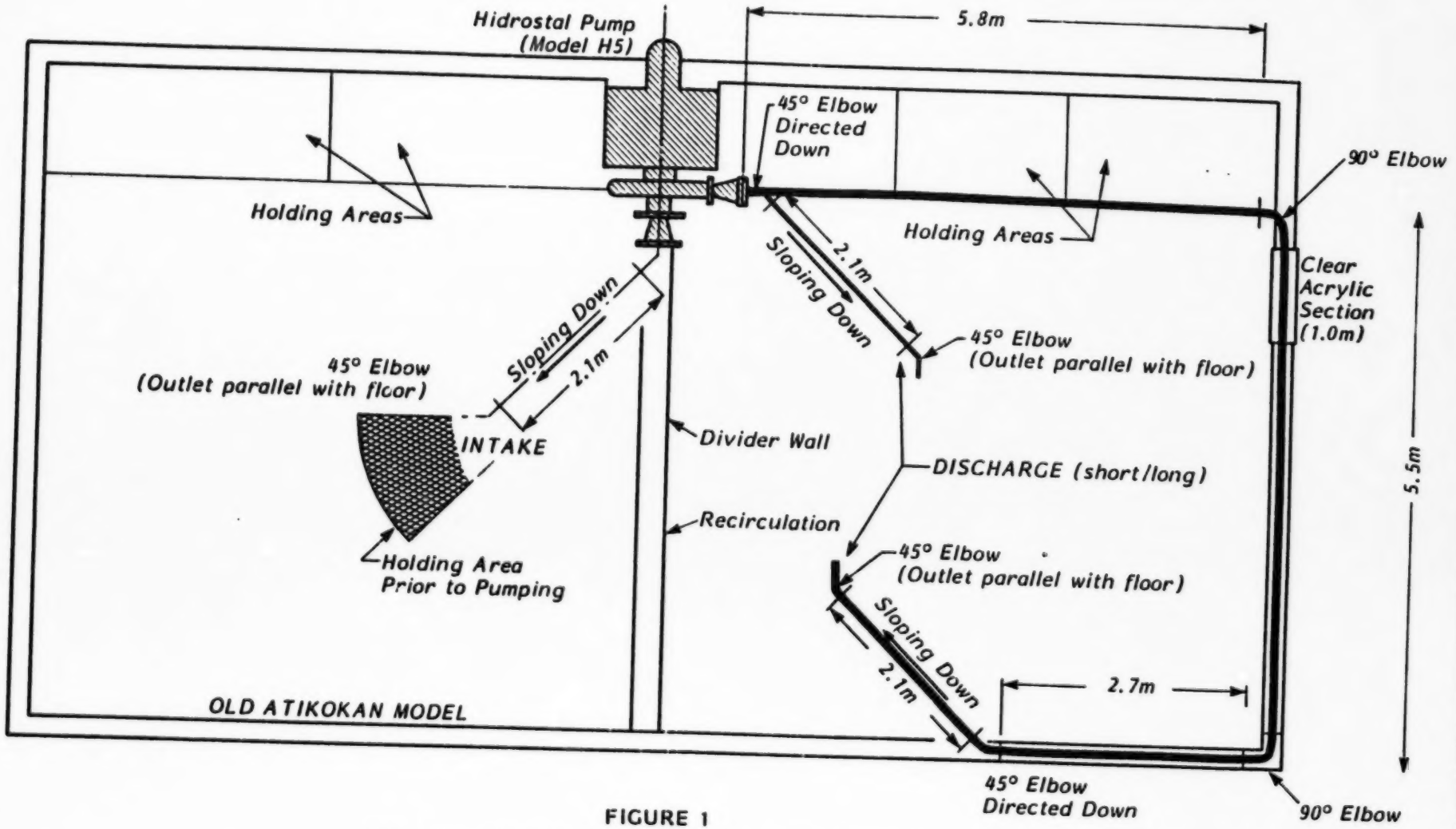


FIGURE 1

GENERAL LAYOUT OF HIDROSTAL PUMP ASSEMBLY
SHOWING BOTH SHORT AND LONG LOOP TRANSPORT SYSTEMS

FIGURE 2

FISH HOLDING AREA AT INTAKE MOUTH

measurements in the long loop system were determined in the clear acrylic section immediately following the initial 90° bend (Figure 1). Pressures within the return pipe were estimated for the long transport system only using a standard vacuum gauge.

2.3 Experimental Design

The effectiveness of the Hidrostal pump in the live transfer of fish was evaluated with respect to pump speed, (436 to 1163), loop system (short, long), fish density (low, high), and fish species (rainbow trout, yellow perch, alewife, smelt). Fish survival for each test was estimated immediately following passage (0 h), and after 24 and 48 h holding periods. In the case of rainbow trout, and yellow perch, fish were also held several months following fish passage. After 48 h, each fish was also assessed (per cent occurrence) for minor injury (bruises, scale loss, etc), and was measured (total length). Similarily, control fish which were run concurrently with experimental fish, were also assessed for mortality, minor injuries (due to handling), and were measured. For each experimental test (loop system, fish density, pump speed), fish survival was estimated relative to a corresponding control test over the 48 h holding period. Fish with minor injuries were categorized as survivors. A summary of minor injuries experienced by fish after pump passage is documented in the text.

In the short loop tests, pumping speeds of 436, 604, 944 and 1163 rpm were used in the experimental design. At these pumping speeds, estimated discharge pipe velocities ranged from approximately 0.70 m/s to 1.72 m/s (Table II). Because of high turbulence it was difficult to obtain reliable pressure estimates for this loop system.

In the long loop transport only pump speeds of 436, 604 and 944 rpm could be achieved. Estimated pipe velocities in the long loop transport were slightly higher than those in the short loop system, and ranged from approximately 0.85 to 1.80 m/s (Table II). These velocity data are only approximate because of high turbulence encountered in the pipe system (confidence limits were not assessed). Estimated pressures in the long loop were negative, and ranged in a drop in atmospheric neutral pressure of 12.5 mm Hg at the 436 rpm pump speed to a drop of 100 mm Hg at the 944 rpm pump speed (Table II).

Low and high fish density tests were conducted separately to simulate both chronic and acute impingement. For each pump combination (pump speed versus loop system), five low-density tests were performed, each with 25 individuals. One hundred individuals of each species were used in the high-density tests. These densities (low, high) correspond to approximately 14 and 55 ind/m^3 (volume in caged area) prior to pumping. Because of availability problems, only one high density test was performed for each pump speed (both loop systems).

TABLE II

ESTIMATED PIPE VELOCITIES AND
PRESSURES FOUND IN SHORT AND LONG LOOP SYSTEMS

Loop System	Pump Speed (rpm)	Pipe Velocity (m/s)	Pressure (maximum mm Hg)
Short	436	0.70	DATA
	604	0.90	NOT
	944	1.40	AVAILABLE
	1163	1.72	
Long	436	0.85	12.5
	604	1.25	45.0
	944	1.80	100.0

In addition to assessing survival and fish injury, observations (visual, closed circuit TV), were made on fish behaviour in the vicinity of the pump prior to and following test trials. An assessment was made of the ability of fish to escape the pump intake.

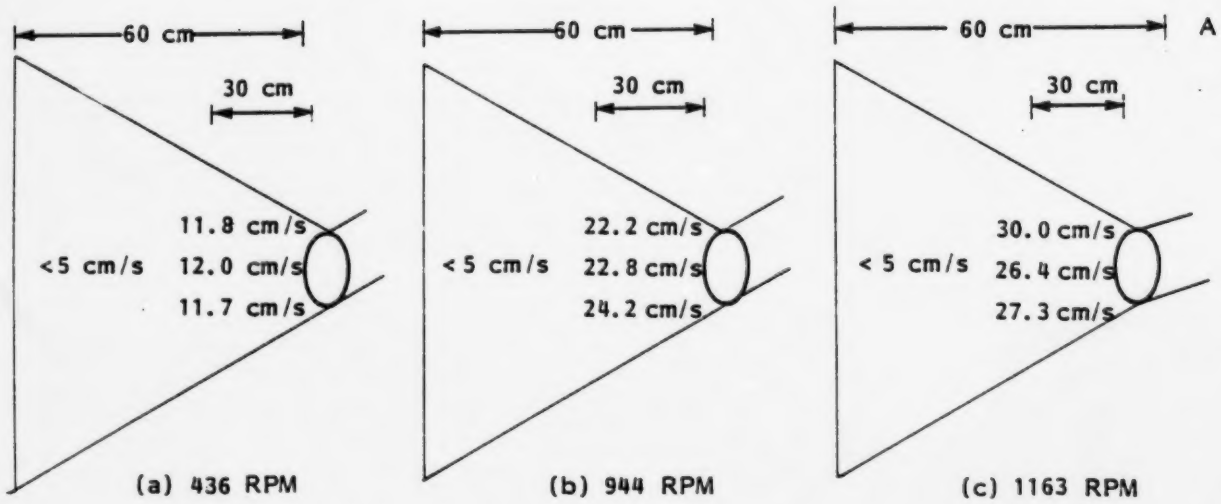
3. RESULTS

3.1 Rainbow Trout

(a) Behavioural Observations

An obvious fish avoidance of the intake area was observed prior to and during pumping, irrespective of transport system (Figure 3). Although fish were rheotaxic in orientation (orientated against current) they preferred areas away from the intake mouth where current velocities in the caged area were lowest (<5 cm/s). (In the presence of strobe light fish were not observed in this area.) At low pump speeds, fish were able to maintain position away from the intake mouth for a considerable time period. However, with an increase in pump speed, it became increasingly difficult for fish to avoid entry into the pump. For example, at a pump speed of 436 rpm, 92% (23 of 25) of the fish were still remaining in the intake holding area after 5 h of operation. However, at a higher pump speed (944 rpm) and correspondingly higher intake velocity (Figure 3), only 30% (8 of 25) of the trout remained after a similar time period. In the absence of a holding (cage) area, casual observations suggested that no trout would be entrained, since fish maintained positions outside the influence of the pump intake current.

In the long loop tests, observations through the acrylic section of the loop system (Figure 1), indicated that fish were propelled in a screw-like manner (Figure 3B). The ability of



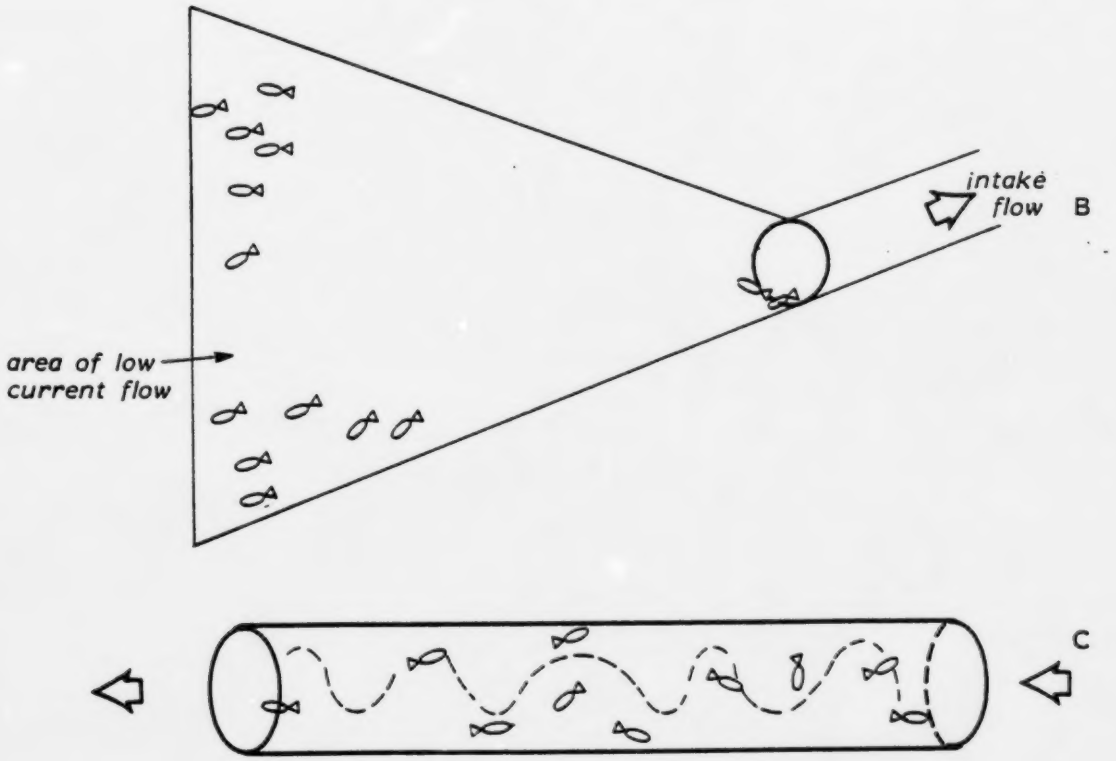


FIGURE 3

A. CURRENT VELOCITIES ESTIMATED NEAR THE INTAKE MOUTH AT VARIOUS PUMP SPEEDS.
B. FISH POSITIONING AND ORIENTATION AT THE INTAKE MOUTH AND DURING PASSAGE THROUGH THE LONG LOOP SYSTEM.

trout to orientate against the current flow decreased as the pump speed increased.

Following discharge, some fish (trout, perch, smelt) were noted to lay on the tank bottom for a short time period (5 to 15 min). Although these fish were not injured, they appeared slightly disoriented.

(b) Fish Survival

(i) Low Density Tests

Rainbow trout survival through both short and long loop transport systems averaged 96.6% over a 48 h period for the various pumping regimes (Figure 4). These estimates of survival have been corrected for mortality in control tests. Fish with minor injuries (eg, scale loss) were classified as survivors, and are discussed later in the text (Table V). A two-way ANOVA was used to evaluate the effect of pumping speed (436 to 1163 rpm) on fish survival for each loop system, and also assess over what time period (0, 24, 48 h) most of the mortality occurred (Table III). Analysis was conducted separately for each loop system. In the short loop tests, the F-test for pump speed was not significant ($F_{3,48} = 2.0$, $p > 0.05$) indicating that there was no mortality difference over the pump speeds tested. In contrast, in the long loop tests, a significant difference in mortality was evident among the various pumping speeds ($F_{2,36} = 18$, $p < 0.05$). Results of a multiple range test indicated that highest survival occurred for both 436 and 604 rpm speeds.

In both short and long loop tests, the F-tests for time were not significant (short $F_{2,48} = 0.01$, $p > 0.05$; long $F_{2,36} = 0.01$, $p > 0.05$, Table III), indicating that there was no significant change in mortality after 48 h compared to mortality immediately following passage.

The type of loop system used for fish transport (short versus long) was also evaluated as a factor influencing fish mortality (Table III). Fish survival after a 48 h period was compared between the two loop systems at pump speeds of 436, 604 and 944 rpm. No significant difference in fish survival was noted between the two loop systems ($F_{1,24} = 0.3$, $p > 0.05$).

For both loop systems, an increase in minor injuries was observed with an increase in pump speed (Table IV). Most of these fish had bruises in the dorsal region which generally cleared up within a few days. Scale loss, qualitatively recorded as low and/or medium, was not attributed solely to pump passage. Handling and the previous use of these fish in other

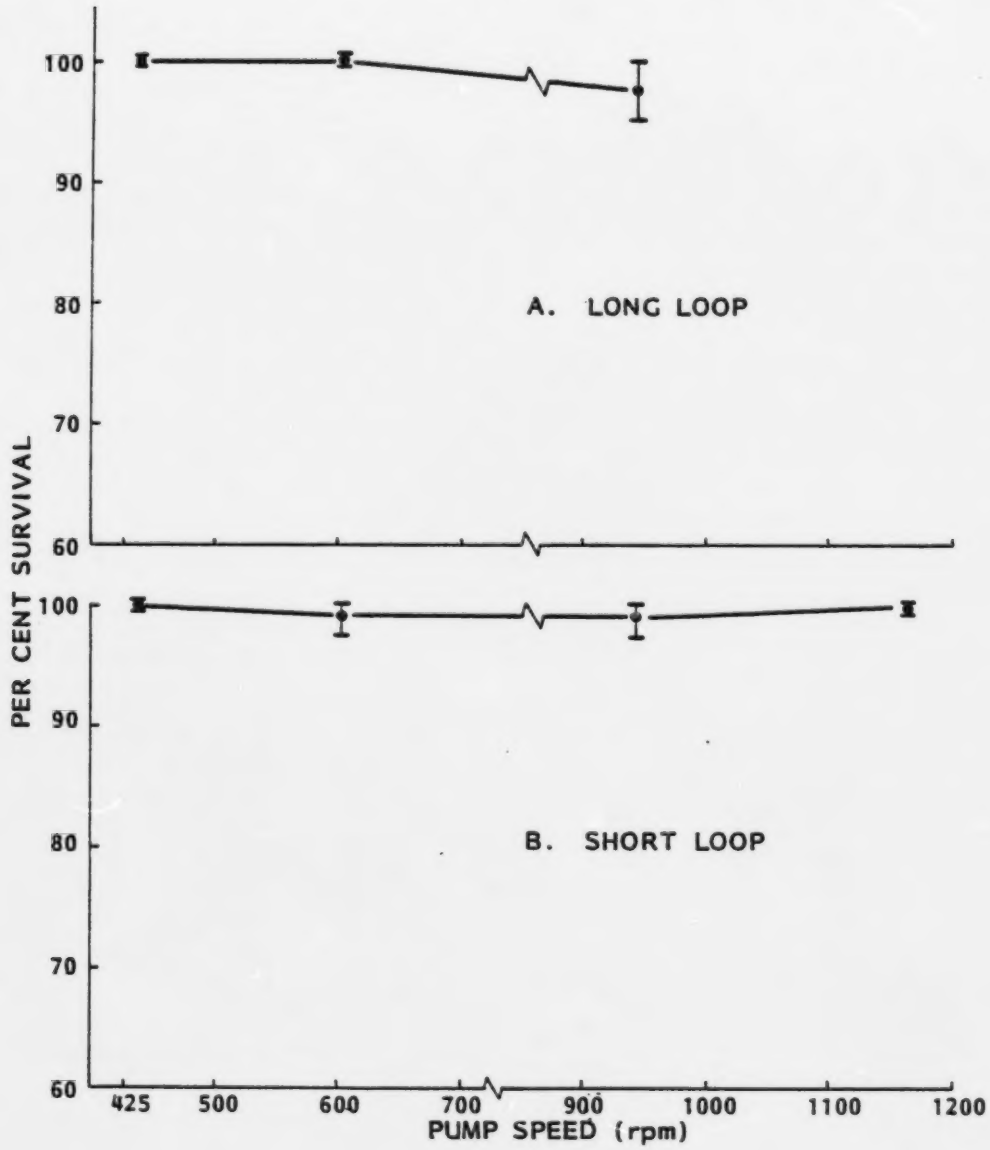


FIGURE 4

RAINBOW TROUT SURVIVAL THROUGH THE HIDROSTAL PUMP
A) LONG LOOP
B) SHORT LOOP
(VERTICAL BARS ARE STANDARD DEVIATIONS)

TABLE III

ANOVA (TWO-WAY) AND MULTIPLE RANGE TEST (S.N.K)
COMPARING THE EFFECTS OF PUMP SPEED, HOLDING TIME, AND LOOP SYSTEM ON RAINBOW TROUT SURVIVAL

(a) Comparison of Effects of Pump Speed Versus Holding Time

	Source	Degrees of Freedom	F-Test	Multiple Range Test (lowest → highest survival
Short Loop	Pump Speed[1]	3	2.0	
	Holding Time[3]	2	0.01	
	Interaction	6	0.01	
	Total	59		
Long Loop	Pump Speed[2]	2	18.0*	94.6 100 100 survival** (%) 944 |604 436| rpm
	Holding Time[3]	2	0.01	
	Interaction	4	0.01	
	Total	44		

(b) Comparison of Effects of Pump Speed Versus Loop System

Source	Degrees of Freedom	F-Test
Loop System (short vs long)	1	0.3
Pump Speed[2]	2	3.7*
Interaction	2	2.0
Total	29	

1. Pump Speeds of 436, 604, 944, 1163 rpm
2. Pump Speed of 436, 604, 944 rpm
3. Holding Times of 0, 24, 48 h

* significant at $p < 0.05$

** survivals are mean estimates following 0, 24 and 48 h after passage.

TABLE IV

SUMMARY OF MINOR INJURIES OBSERVED FOR RAINBOW TROUT AFTER PASSAGE (48 h) THROUGH THE HIDROSTAL PUMP

Loop System	Pump Speed (rpm)	Sample Size	Total Injured (minor)	Type of Injury* (%)						Mean Size** Injured Fish (cm) ($\bar{x}$±/SD)	Mean Size ** Experimental Fish (cm) ($\bar{x}$±SD)
				H	B	F	BE	C	SL (low, medium, high)		
Short	436	125	3	0	100	0	0	0	L	16.4±2.2	16.2±2.0
	604	125	4	50	0	0	50	0	L	14.9±3.9	16.2±1.8
	944	125	14	0	100	0	0	0	L-M	16.7±1.5	16.7±1.7
	1163	125	50	0	96	0	2	2	L-M	17.5±4.1	18.4±1.6
Long	436	125	1	0	100	0	0	0	L	18.2	17.0±2.0
	604	125	6	0	96	0	0	0	L	18.3±1.4	17.2+1.9
	944	125	13	7.6	76.9	0	0	0	L-M	16.4±1.9	16.9±2.2

* H - Hemorrhage
B - Bruise
F - Fungus
BE - Bulged Eyes
C - Cuts
SL - Scale Loss

** No significant difference at P>0.05

TABLE V

RAINBOW TROUT MORTALITY AND INJURY RESULTING FROM HIGH DENSITY PASSAGE (48 h) THROUGH THE HIDROSTAL PUMP

Loop System	Pump Speed (rpm)	Sample Size	Mortality (%)	Total Injured (minor)	Type of Injury (%)					
					Hemorrhage	Bruise	Fungus	Bulged Eyes	Cuts	Scale Loss (low, medium, high)
Short	436	100	0	0	0	0	0	0	0	L
	604	100	0	0	0	0	0	0	0	L
	944	100	0	6	0	83.3	0	16.7	0	L-M
	1163	100	0	2	0	100	0	0	0	L-M
Long	436	100	0	1	100	0	0	0	0	L
	604	100	0	1	0	0	0	0	100	L
	944	100	0	8	14.5	85.5	0	0	0	L-M

COTC studies (eg, louvres) contributed to some scale loss[1]. However, the contribution of this loss could not be assessed quantitatively. Assuming all injured fish later died, trout survival for the long loop transfer system at pump speeds of 436 and 604 rpm would still exceed 98 and 85%, respectively.

Differences noted betwen size of fish and frequency of injury resulting from pump passage were not significant (Table IV).

(ii) High Density Tests

No mortality was recorded in the high density tests irrespective of pumping regime (Table V). Similar to results observed in the low density tests, an increase in minor injuries was evident at the higher pump speeds.

3.2 Yellow Perch

(a) Behavioural Observations

As with rainbow trout, yellow perch showed a strong avoidance of the intake area (Figure 3), and could only be successfully directed into the intake pipe by the use of strobe lights and nets.

(b) Fish Survival

(i) Low Density Tests

Yellow perch survival after 48 h exceeded 90% in both short and long loop transport systems (Figure 5). With an increase in pump speed, there was a general decreasing trend in fish survival. However, this trend was only significant for the short loop tests ($F_{3,48} = 3.5$, $p < 0.05$, Table VI), and results of a multiple range test suggested that lowest survival was obtained at the 1163 rpm pump speed. For both loop tests, the F-test comparing time was not significant indicating that there was no appreciable increase in mortality up to 48 h following pump passage (short loop, $F_{2,48} = 2.1$, $p > 0.05$; long loop $F_{2,36} = 2.8$, $p > 0.5$).

The type of transport system (short versus long loop) was also evaluated as a factor influencing fish survival (Table VI). Results indicated no significant difference in mortality between the two transport systems ($F_{1,24} = 1.5$, $p > 0.05$). In addition, results also showed that pump speed had no significant influence on fish survival after combining both short and long loop data for pump speeds up to 944 rpm ($F_{2,24} = 0.9$, $p > 0.05$).

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[1] Scale loss was the only significant injury noted for fish prior to pump passage.

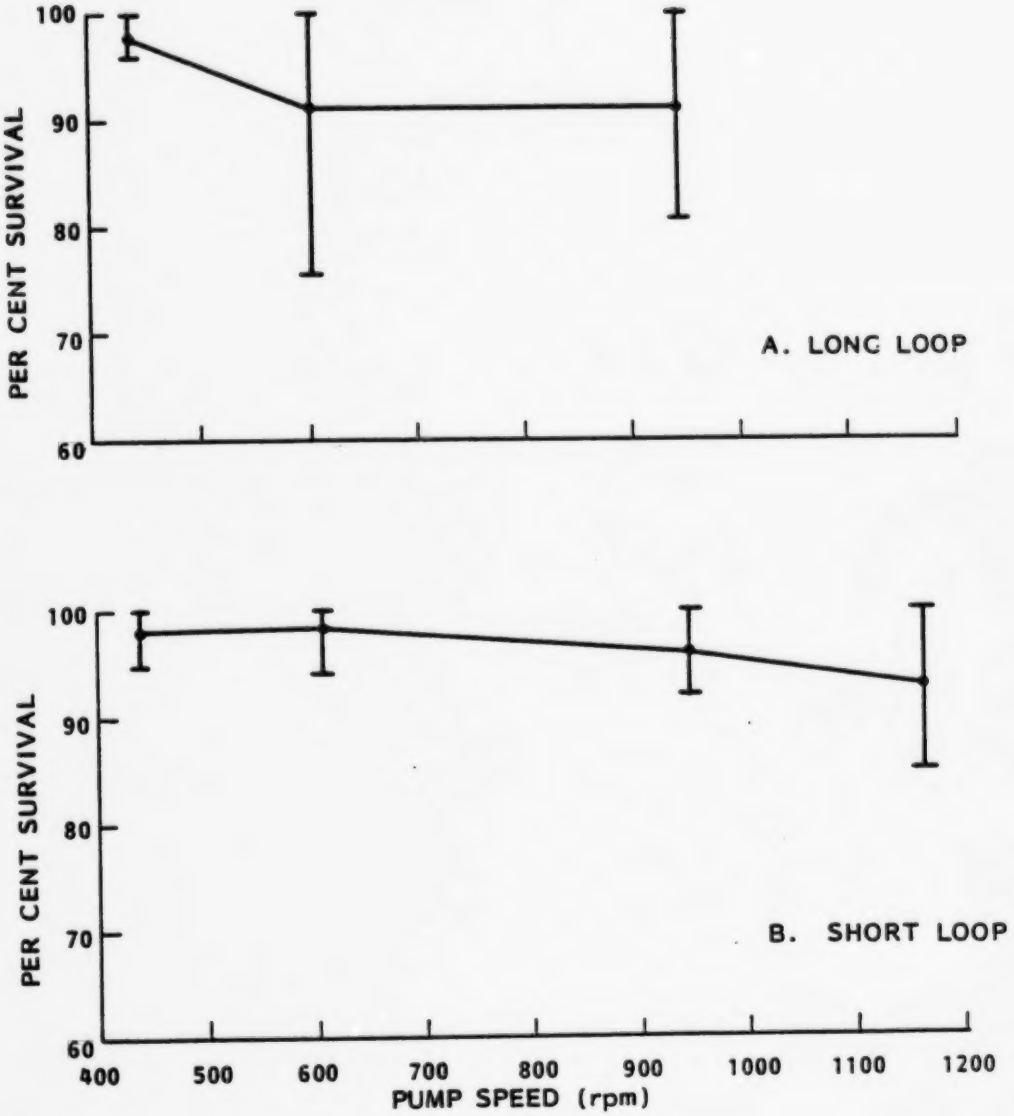

FIGURE 5

YELLOW PERCH SURVIVAL THROUGH THE HIDROSTAL PUMP
A. LONG LOOP B. SHORT LOOP
(VERTICAL BARS ARE STANDARD DEVIATIONS)

TABLE VI

ANOVA (TWO-WAY) AND MULTIPLE RANGE TEST (S.N.K)
COMPARING THE EFFECTS OF PUMP SPEED, HOLDING TIME, AND LOOP SYSTEM ON YELLOW PERCH SURVIVAL

(a) Comparison of Effects of Pump Speed Versus Holding Time

	Source	Degrees of Freedom	F-Test	Multiple Range Test (lowest → highest survival)
Short Loop	Pump Speed[1]	3	3.5*	94.9 97.9 98.4 99.2 survival** (%)
	Holding Time[3]	2	2.1	1163 944 604 436 rpm
	Interaction	6	0.1	
	Total	59		
Long Loop	Pump Speed[2]	2	1.6	
	Holding Time[3]	2	2.8	
	Interaction	4	0.4	
	Total	44		

(b) Comparison of Effects of Pump Speed Versus Loop System

Source	Degrees of Freedom	F-Test
Loop System (short vs long)	1	1.5
Pump Speed[2]	2	0.9
Interaction	2	0.4
Total	29	

1. Pump Speeds of 436, 604, 944, 1163 rpm
2. Pump Speed of 436, 604, 1163 rpm
3. Holding Times of 0, 24, 48 h

* significant at $p < 0.05$

** survivals are mean estimates following 0, 24 and 48 h after passage.

TABLE VII

SUMMARY OF MINOR INJURIES OBSERVED FOR YELLOW PERCH AFTER PASSAGE (48 h) THROUGH THE HIDROSTAL PUMP

Loop System	Pump Speed (rpm)	Sample Size	Total Injured (minor)	Type of Injury* (%)						Mean Size** Injured Fish (cm) ($\bar{x}$±SD)	Mean Size ** Experimental Fish (cm) ($\bar{x}$±SD)
				H	B	F	BE	C	SL (low, medium, high)		
Short	436	125	11	18.2	63.6	1.0	0	1.0	L	13.9±2.6	13.6±2.5
	604	125	3	66.6	33.3	0	0	0	L	15.7±2.9	13.3±2.5
	944	125	3	33.3	0	0	0	66.6	L	13.8±2.0	14.2±2.6
	1163	125	8	62.5	0	0	12.5	25.0	L	13.3±1.7	13.6±2.3
Long	436	125	0	0	0	0	0	0	L	-	12.5±1.6
	604	125	6	16.7	50.0	16.7	0	16.7	L	12.8±1.2	12.3+1.4
	944	125	22	31.8	59.1	31.8	4.5	0	L	13.6±3.1	13.6±2.3

** No significant difference at P>0.05

* H - Hemorrhage
B - Bruise
F - Fungus
BE - Bulged Eyes
C - Cuts
SL - Scale Loss

TABLE VIII

YELLOW PERCH MORTALITY AND INJURY RESULTING FROM HIGH DENSITY PASSAGE (48 h) THROUGH THE HIDROSTAL PUMP

Loop System	Pump Speed (rpm)	Sample Size	Mortality (%)	Total Injured (minor)	Type of Injury (%)					
					Hemorrhage	Bruise	Fungus	Bulged Eyes	Cuts	Scale Loss (low, medium, high)
Short	436	100	11	7	42.9	14.3	28.6	-	14.3	L
	604	100	12	2	100.0	-	-	-	-	L
	944	100	8	7	100.0	-	-	-	-	L
	1163	100	5	9	22.2	66.7	-	11.1	-	H

For the long loop transport system, there was a noticeable increase in the number of minor injuries associated with an increase in pump speed (Table VII). However, in the short loop system most injuries occurred at the 436 rpm speed. Many fish suffered bruise-related injuries which generally cleared up within a few days. Few fish were actually cut, and scale loss was minimal. All fish in the injured category survived, and there was no indication of latent mortality several weeks following pump passage. Even if all injured fish were classified as dead, survival for the long transport system at pump speeds of 436 and 604 rpm would still exceed 95% and 85% respectively. Perch survival for the short loop system also exceeded 85% for these pump speeds.

As with rainbow trout, there was no apparent relationship between size of fish and frequency of injury (Table VII).

(ii) High Density Tests

Yellow perch survival exceeded 88% for the high density tests with the short loop system (Table VIII). There was no significant relationship between pump speed and fish survival/injury, although highest survival was obtained at 1163 rpm. Most of the fish injured at pump speeds of 604 and 944 rpm showed slight hemorrhaging, which generally cleared up in a few days.

3.3 Alewife

(a) Behaviour Observations

Similar to other species, alewife showed a strong avoidance of the intake area (Figure 3).

(b) Fish Survival

(i) Low Density Tests

Alewife survival after 48 h averaged 84.6% for the short loop system, and 91.2% for the long loop system (Figure 6). Generally survival decreased with an increase in pump speed (except 436 rpm, short loop). The lower than expected survival at the 436 rpm short loop system was attributed to fish being in poor condition which resulted in a high standard deviation in the mean survival estimate. Control fish which were run concurrently with experimental fish were also noted to be in poor condition (Appendix 3). A two-way ANOVA was used to compare statistically the effect of pump speed (rpm) on fish survival, and also assess over what time period most of the mortality occurred (Table IX). For both short and long loop systems, the F-tests for pump speed were significant, indicating that fish survival was dissimilar for at least one pump speed (short loop $F_{3,48} = 8.2$, $p < 0.05$; long loop $F_{2,36} = 6.0$, $p < 0.05$). A multiple range test indicated that for each loop

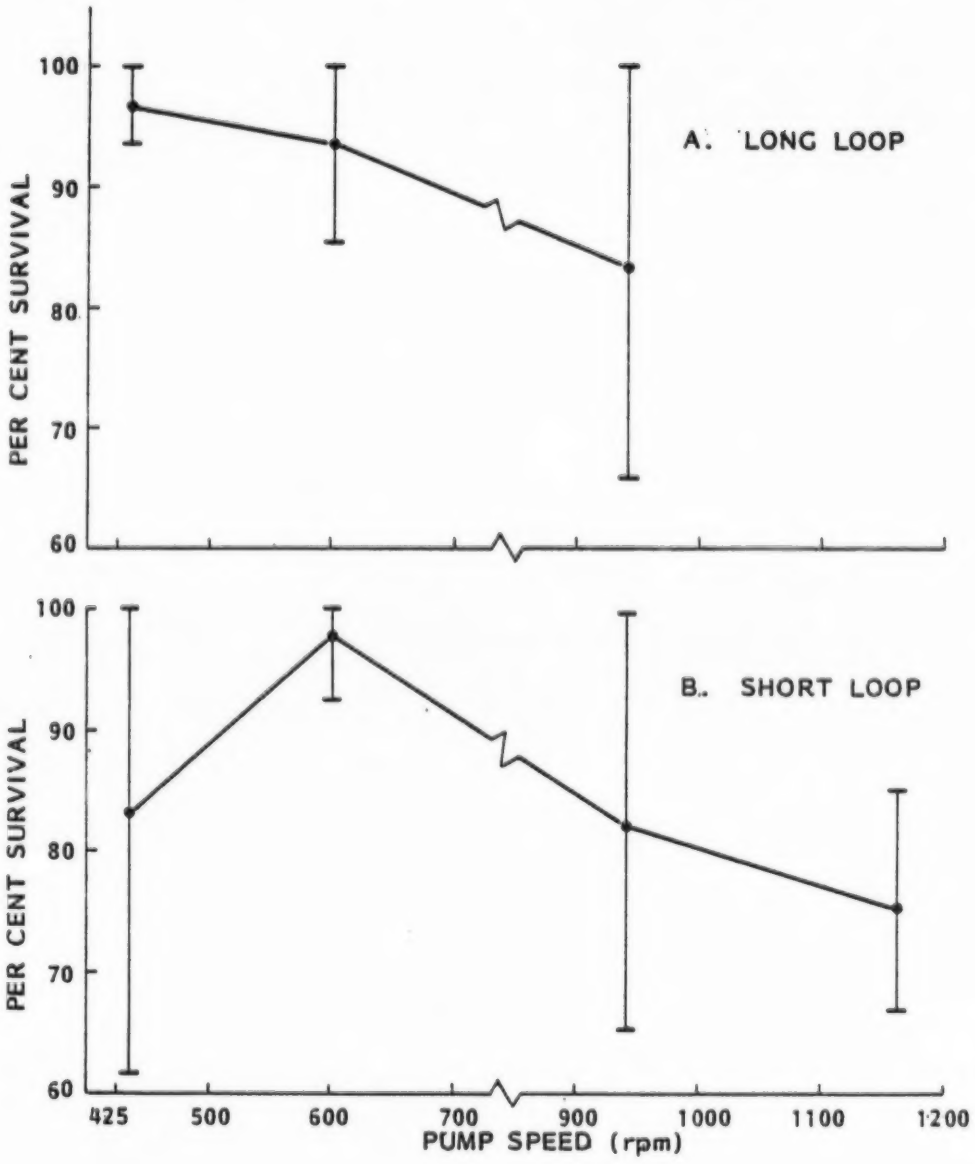

FIGURE 6

ALEWIFE SURVIVAL THROUGH THE HIDROSTAL PUMP
A) LONG LOOP
B) SHORT LOOP
(VERTICAL BARS ARE STANDARD DEVIATIONS)

TABLE IX

ANOVA (TWO-WAY) AND MULTIPLE RANGE TEST (S.N.K)
COMPARING THE EFFECTS OF PUMP SPEED, HOLDING TIME, AND LOOP SYSTEM ON ALEWIFE SURVIVAL

(a) Comparison of Effects of Pump Speed Versus Holding Time

	Source	Degrees of Freedom	F-Test	Multiple Range Test (lowest → highest survival
Short Loop	Pump Speed[1]	3	8.2*	78.7 84.5 91.2 97.9 survival** (%)
	Holding Time[3]	2	2.3	1163 944 436 604 rpm
	Interaction	6	0.5	
	Total	59		
Long Loop	Pump Speed[2]	2	6.0*	88.8 96.8 98.4 survival** (%)
	Holding Time[3]	2	2.7	944 604 436 rpm
	Interaction	4	0.3	
	Total	44		

(b) Comparison of Effects of Pump Speed Versus Loop System

Source	Degrees of Freedom	F-Test
Loop System (short vs long)	1	0.5
Pump Speed[2]	2	2.1
Interaction	2	1.1
Total	29	

1. Pump Speeds of 436, 604, 944, 1163 rpm
2. Pump Speed of 436, 604, 944 rpm
3. Holding Times of 0, 24, 48 h

* significant at $p<0.05$

** survivals are mean estimates following 0, 24 and 48 h after passage.

TABLE X

SUMMARY OF MINOR INJURIES OBSERVED FOR ALEWIFE AFTER PASSAGE (48 h) THROUGH THE HIDROSTAL PUMP

Loop System	Pump Speed (rpm)	Sample Size	Total Injured (minor)	Type of Injury* (%)						Mean Size** Injured Fish (cm) ($\bar{x}$±/SD)	Mean Size ** Experimental Fish (cm) ($\bar{x}$±SD)
				H	B	F	BE	C	SL (low, medium, high)		
Short	436	125	20	80.0	5.0	10.0	0	5.0	L	15.3±0.8	15.2±1.3
	604	125	28	60.7	7.1	28.6	0	3.6	M-H	14.9±1.1	14.8±1.0
	944	125	33	12.1	72.7	6.0	6.0	3.0	M-H	13.6±1.2	14.0±3.7
	1163	125	46	23.9	54.2	2.1	10.9	8.6	M-H	13.9±1.3	13.7±1.2
Long	436	125	1	100.0	0	0	0	0	L	15.4	13.8±0.9
	604	125	8	62.5	13.0	25.0	0	0	M	13.8±0.9	14.7+1.0
	944	125	16	81.3	0	6.3	635	6.3	H	14.1±0.8	13.8±0.9

* H - Hemorrhage
B - Bruise
F - Fungus
BE - Bulged Eyes
C - Cuts
SL - Scale Loss

** No significant difference at P>0.05

system, highest mortality generally occurred at the highest pump speeds.

In both short and long loop tests, the F-tests for time were not significant; short ($F_{2,48} = 2.3$, $p > 0.05$; long ($F_{2,36} = 2.7$, $p > 0.05$), indicating that there was no significant increase in mortality after 48 h compared to mortality immediately following passage (0 h).

The type of transport system (short versus long) was also evaluated as a factor influencing fish mortality (Table IX). Results indicated no significant difference in survival between the two loop systems ($F_{1,24} = 0.5$, $p > 0.05$).

For both loop systems, there was a noticeable increase in the number of injured fish as pumping speed increased (Table X). Generally, most of these fish suffered hemorrhaging and there was a greater proportion of fish with bruises at the higher pumping speeds. These bruises gradually disappeared, and did not appear to affect fish survival. For both loop systems, less than 10% of the injured fish received cuts. Scale loss for alewife passage was noticeably high, especially at the higher pump speeds. In addition to pump passage, significant scale loss was also attributed to handling (moving fish from discharge area to holding area, Figure 1). Even control fish were noted to have excessive scale loss which resulted from net damage as they were transported to holding areas (Figure 1). Assuming all injured fish later died, alewife survival for the long loop systems at pump speeds of 436 and 604 rpm would exceed 94 and85% respectively. However, it should be noted that fish survival (assuming all injured fish die) would be significantly lower for the short loop tests since fish were in poorer condition (as noted previously in Materials and Methods). As with other species, there was no relationship found between size of fish and frequency of injury (Table X).

(ii) High Density Test

Because of fish availability problems, only one high density (n = 100) replicate was performed. At a pump speed of 436 rpm all fish were passed successfully with only one individual showing a minor injury (hemorrhage in dorsal region).

3.4 Rainbow Smelt

(a) Behavioural Observations

Similar to all other species, smelt were observed to show a strong avoidance of the intake area (Figure 3).

(b) Fish Survival

Because of fish availability problems, only low density long loop transport tests were performed. Fish survival after 48 h

averaged 90.1% over the pumping speeds tested, with a noticeable decrease in survival with an increase in pump speed (Figure 7). Results of a two-way ANOVA indicated that smelt survival varied significantly over the pump speeds tested ($F_{2,36} = 72.7$, $p < 0.05$, Table XI). A follow-up multiple range test suggested that for each time period, mortality was lowest for both 436 and 604 rpm pump speeds, and highest at the 944 rpm speed. The F-test comparing time was not significant ($F_{2,36} = 3.0$, $p > 0.05$) indicating that fish mortality did not increase appreciably 48 h after the initial passage.

TABLE XI

ANOVA (TWO-WAY) AND MULTIPLE RANGE TEST (S.N.K.) COMPARING THE EFFECTS OF PUMP SPEED AND HOLDING TIME ON SMELT SURVIVAL

(a) ANOVA Results

Source	Degrees of Freedom	F-Test
Pump Speed[1]	2	72.7*
Holding Time[2]	2	3.0
Interaction	4	6.5*
Total	44	

1. Pump Speeds of 436, 604, 944 rpm
2. Holding Times of 0, 24, 48 h
* Significant at P<0.05

(b) Multiple Range Tests

Comparison (time in h)	Range Lowest → Highest Survival**			
0	55.2	95.2	100	survival (%)
	944	604	436	rpm
24	64.8	95.2	96.8	survival (%)
	944	604	436	rpm
48	81.6	92.0	96.8	survival (%)
	944	604	436	rpm

** Survival are mean estimates following 0, 24 and 48 h after passage

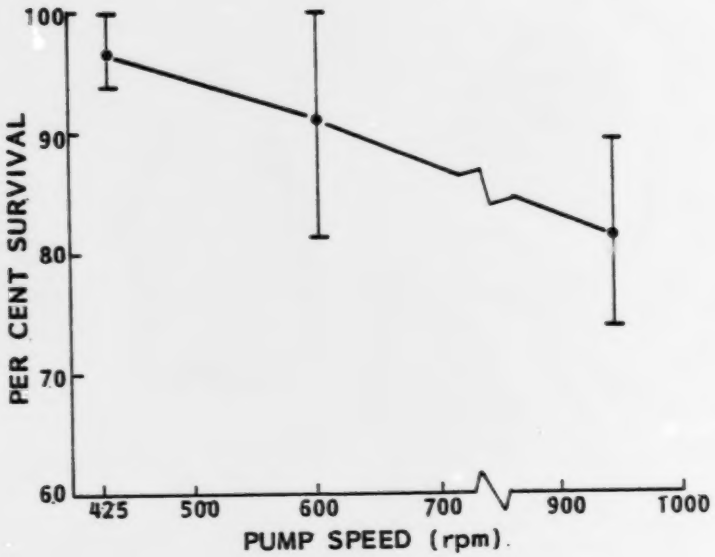

FIGURE 7

SMELT SURVIVAL THROUGH THE LONG LOOP
TRANSPORT OF THE HIDROSTAL PUMP
(VERTICAL BARS ARE STANDARD DEVIATIONS)

TABLE XII

SUMMARY OF MINOR INJURIES OBSERVED FOR SMELT
AFTER PASSAGE (48 h) THROUGH THE HIDROSTAL PUMP

Loop System	Pump Speed (rpm)	Sample Size	Total Injured (minor)	Type of Injury* (%)						Mean Size** Injured Fish (cm) ($\bar{x}$±/SD)	Mean Size ** Experimental Fish (cm) ($\bar{x}$±SD)
				H	B	F	BE	C	SL (low, medium, high)		
Long	436	125	9	22.2	33.3	33.3	0	11.1	L	15.5±0.8	14.6±2.4
	604	125	27	25.9	3.7	66.7	0	3.7	L	15.0±1.9	14.8+1.7
	944	125	18	61.1	11.1	16.7	0	11.1	L	14.7±2.6	14.4±2.1

* H - Hemorrhage
B - Bruise
F - Fungus
BE - Bulged Eyes
C - Cuts
SL - Scale Loss

** No significant difference at P>0.05

Highest number of minor injuries were recorded at 604 rpm followed by 944 rpm and 436 rpm pump speeds (Table XII). It is also noteworthy that fish tested at the 604 rpm had a higher occurrence of fungus suggesting that these fish were in poorer condition than fish used at the other pump speeds. High occurrence of fungus was also noted in control fish. Although mortality was not evident 48 h after passage, it was suspected that these fish would eventually die from fungal infection (unrelated to pump passage). The number of cuts noted for smelt was less than 12% of all injured fish irrespective of pumping speeds. Assuming all injured fish did not survive, smelt survival for the long loop system at pump speeds of 436 and 604 rpm would average approximately 89% and 70% respectively (does not take into account control fish with fungus which may later die).

Similar to other species, there was no relationship between size of fish and frequency of injury (Table XII).

3.5 Comparison of Survival Between Fish Species

A comparison of fish survival between species for various pump speeds through the long loop transport system is shown in Figure 8. Differences in survival among species were more evident at the higher pump speeds. Generally, survival appeared highest for rainbow trout, and lowest for smelt. Results of a two-way ANOVA and multiple range test indicated that survival varied significantly between species ($F_{3,48} = 3.1$, $p < 0.05$), with highest survival occurring for rainbow trout and yellow perch, followed by alewife and smelt (Table XIII). For all species combined, pump speed significantly affected fish survival ($F_{2,48} = 5.9$, $p < 0.05$) with highest survival occurring at pump speeds of 436 and 604 rpm.

3.6 Other Species

Juvenile gizzard shad, brown bullhead and white suckers were also passed successfully through the Hidrostal pump at speeds of 604 and 944 rpm (Table XIV). Length, depth and numbers of fish used in passage tests are indicated. Some fish, such as suckers, exceeded 39 cm in length; and were approximately 7.5 cm in depth.

4. DISCUSSION

4.1 Fish Survival

Overall, fish survival averaged approximately 93% for all pumping regimes through both transport systems. Survival was highest for the more robust laboratory-reared rainbow trout, and lowest for the two pelagic schooling species, smelt and alewife. Still, survival for these latter species averaged approximately 87% over both transport systems (including the

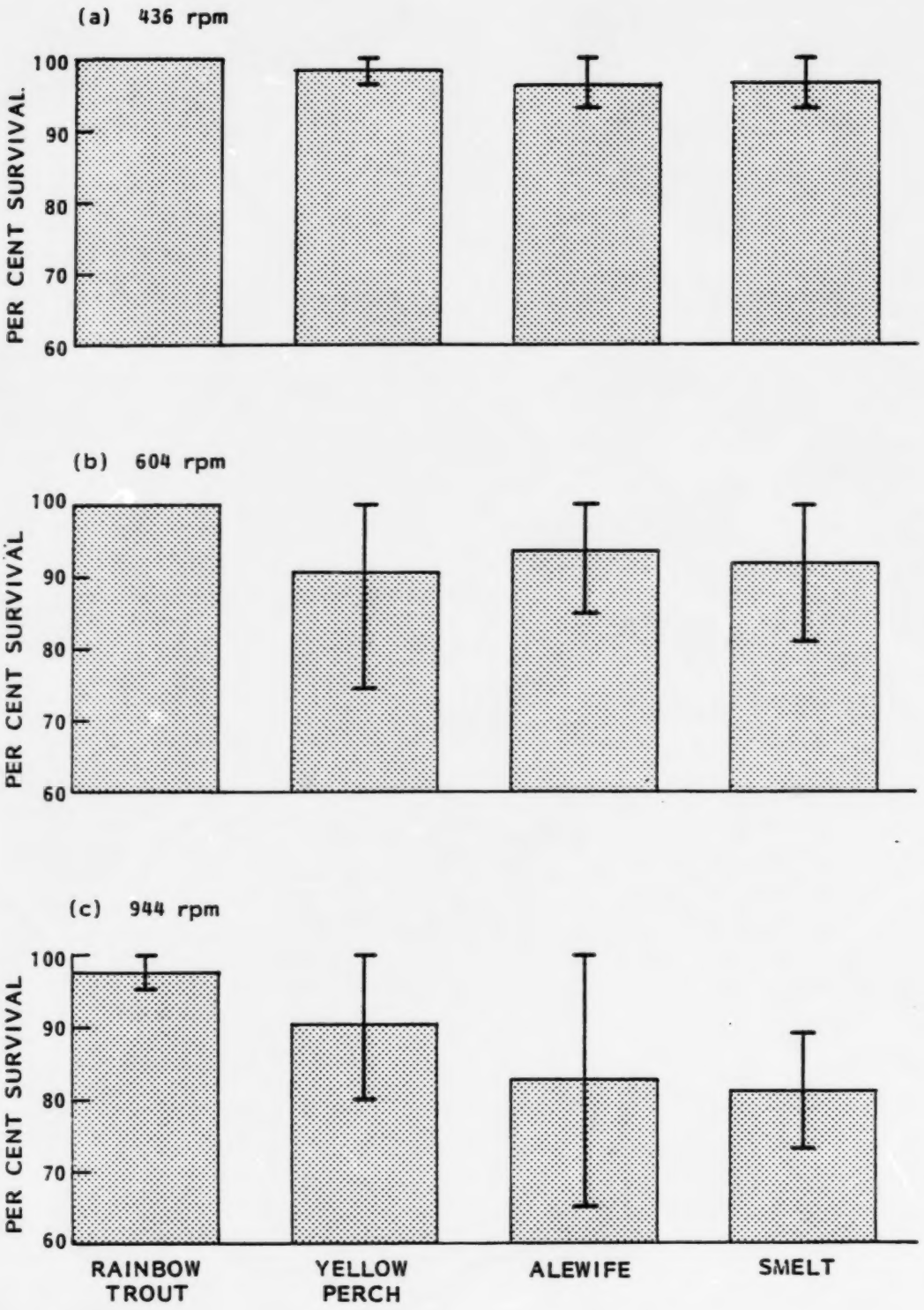

FIGURE 8

COMPARISON OF SURVIVAL BETWEEN RAINBOW TROUT, YELLOW PERCH, ALEWIFE AND SMELT AT VARIOUS PUMP SEEDS (LONG LOOP)

TABLE XIII

MULTIPLE RANGE TEST (S.N.K.) COMPARING SURVIVAL BETWEEN SEVERAL FISH SPECIES OVER VARIOUS PUMP SPEEDS

Comparison	Range Test (Highest → Lowest)				
Species	Rainbow Trout	Yellow Perch	Alewife	Smelt	Species
	99.2	93.6	91.2	90.1	Survival (%)*
Pump Speed	436	604	944		Pump Speed (rpm)*
	98.0	94.2	88.4		Survival (%)

* Survival after 48 h

TABLE XIV

SURVIVAL OF JUVENILE GIZZARD SHAD, BROWN BULLHEAD AND WHITE SUCKERS THROUGH THE HIDROSTAL PUMP

Species	Number	Approximate Depth (cm)	Length (Range - cm)	Prime Speed (rpm)	Loop System	Survival - 48 h (%)
Gizzard Shad	156	2.0 - 5.5	9.6 - 18.0	604	Short	100
Brown Bullhead	15	5.0 - 6.0	19.0 - 27.8	944	Long	100
White Sucker	20	5.0 - 7.5	16.6 - 39.5	944	Long	100

high pump speeds), which is exceptional, considering that these fish are extremely susceptible to handling. However, it should be noted that tests were conducted on late spring and summer alewife which are generally in better condition than spring fish. If all injured (minor) fish died later, survival may average considerably less. With the exception of rainbow trout and yellow perch, mortality estimates for the other species tested were relatively short term (48 h). Because of holding and maintenance difficulties, longer term tests were not feasible.

For each species, no relationship was found between fish length and injury over the size ranges tested. Although this relationship has been frequently observed in the literature, (eg, turbines - Ruggles and Collins 1981), it should be emphasized that fish depth rather than length may be the critical factor influencing mortality through the Hidrostal pump. The pump has no blades but instead has a screw-type impeller which allowed fish ranging in size from 8 to 40 cm to successfully pass through the pump. Fish approximating 7.5 cm in depth (such as the suckers tested) probably represent the upper limit for this pump model (H5). Still, survival as a function of body length and depth is not known. It is noteworthy that this model is still less than half the size (pump diameter) of the model projected for field use at the Thunder Bay GS installation. Even larger pumps are planned for Darlington GS. It is expected that most Great Lakes species should have little difficulty passing through such units.

4.2 Effects of Pump Speed and Transport System on Fish Survival

Generally, for most species tested, an increase in fish mortality and/or minor injury was associated with an increase in pumping speed. For both loop systems, highest survival generally occurred at 436 rpm and 604 rpm speeds ($\bar{x} \approx 96\%$), whereas lowest survival generally was evident at the 944 rpm and 1163 rpm speeds ($\bar{x} \approx 89\%$). These higher pumping rates resulted in an obvious increase in both the extent of visible damage (bruises, hemorrhages, cuts, scale loss) and probable physiological (hemorrhages, eyes popping) damages. It is not known whether these damages were related to pipe velocities, or pressures, or both. For all species tested, there was no apparent difference in mortality between short and long transport systems, suggesting that length of pipe (and additional bends) may not critically affect fish survival after the initial passage through the pump, given the pipe velocities used in this study (0.7 to 1.8 m/s).

However, the laboratory system is of a small scale relative to the proposed field installations. For this reason, laboratory results should be treated as preliminary, and a complete evaluation of the Hidrostal pump complex must be made in the field.

Based on laboratory results, a pumping speed between 436 rpm and 604 rpm is suggested in the field design for optimal fish survival. Fish survival would average approximately 96% for both loop systems. However, an obvious shortcoming of these lower pump speeds is that fish can actively avoid the intake area for a considerable time period before being passed through the system. The intake velocities created by the pump do not appear sufficient to entrain the fish. Consequently, further development work is required to increase the efficiency of the Hidrostal in removing fish. A behavioural method is preferred since it involves little or no handling of fish prior to pumping. One approach that appears promising is the use of light as a combined attractant/repellant system.

Initially, filtered mercury vapour light could be used to attract fish near the vicinity of the pump intake (OHRDR 80-413-K). At predetermined time intervals (dependent on fish density), high intensity strobe lights would next be used to force fish into the intake pipe. Preliminary results indicate that fish avoid this light source and will enter the intake pipe. The need for a system to guide fish towards the pump was also expressed by the ESERCO group currently evaluating a Hidrostal pump in New York state (Holsapple, pers comm).

5. CONCLUSIONS

1. The effectiveness of the Hidrostal pump in the live transfer of fish was evaluated in the laboratory at pump speeds ranging from 436 to 1163 rpm. Rainbow trout, yellow perch, alewife and smelt were used as test species in this investigation.

2. Fish survival varied with pump speed, transport loop system and with species. Generally, fish survival decreased significantly with an increase in pump speed. No significant difference in mortality occurred comparing fish transport through both short and long loop systems. Over a 48 h period highest survival was obtained with rainbow trout and yellow perch, followed by alewife and smelt. Latent mortality was not observed for rainbow trout and yellow perch held several months following passage.

3. Generally, the number of minor injuries increased significantly with an increase in pump speed. Fewest minor injuries were recorded at 436 and 604 rpm pump speeds. No relationship was found between pump speeds, size of fish and mortality and/or injury.

4. The Hidrostal pump shows promise as part of a fish handling facility. Based on laboratory results, a pumping speed between 436 rpm and 604 rpm is suggested in the field design for optimal fish survival.

5. All species showed a marked avoidance of the intake area prior to pumping, indicating the need for developing an adequate fish extraction system. One approach of particular interest is the use of light as a combined attractant/repellant system.

Approved:

C.H. Clark
Manager
Chemical Research Dept

PHP:lg

Submitted:

P.H. Patrick
Research Biologist
Biological Research Section

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APPENDIX 1. Mortality of Rainbow Trout in A) Short and Long Loop Experimental Pump Tests and B) Controls

Loop System	SHORT LOOP																				LONG LOOP															
Pump Speed (rpm)	436					604					944					1163					436					604					944				
Number of Fish	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	0								1		1																				1			1	1
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25	0																																		
TOTAL	0								1		1																				1			1	1

APPENDIX 1 continued... B. Mortality in Controls

Loop System	SHORT LOOP																				LONG LOOP															
Pump Speed (rpm)	436					604					944					1163					436					604					944				
Number of Fish	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
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TOTAL																																			

APPENDIX 2. Mortality of Smelt in A) Long Loop Experimental Pump Tests and B) Controls

Loop System	SHORT LOOP																				LONG LOOP																	
Pump Speed (rpm)	436					604					944					1163					436					604					944							
Number of Fish	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1																					1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2																						1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3																										1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4																											1	1	1	1	1	1	1	1	1	1	1	1	1	1
5																											1	1	1	1	1	1	1	1	1	1	1	1	1	1
6																												1	1	1	1	1	1	1	1	1	1	1	1	1
7																												1	1	1	1	1	1	1	1	1	1	1	1	1
8																												1	1	1	1	1	1	1	1	1	1	1	1	1
9																												1	1	1	1	1	1	1	1	1	1	1	1	1
10																												1		1	1	1	1	1	1	1	1	1	1	1
11						N	O		D	A	T	A																1		1	1	1	1	1	1	1	1	1	1	1
12																														1	1	1	1	1	1	1	1	1	1	1
13																														1	1	1	1	1	1	1	1	1	1	1
14																														1	1	1	1	1	1	1	1	1	1	1
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TOTAL																					1	2		1	2	3	5	12	10	16	16	15	10	11	12					

APPENDIX 2 continued..... B) Mortality in Controls

Loop System	SHORT LOOP																				LONG LOOP															
Pump Speed (rpm)	436					604					944					1163					436					604					944				
Number of Fish	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1																					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2																					1	1		1	1	1	1	1	1	1	1	1	1	1	1
3																								1		1	1	1	1	1	1	1	1	1	1
4																										1	1	1	1	1	1	1	1	1	1
5																										1	1	1	1	1	1	1	1	1	1
6																										1	1	1	1	1	1	1	1	1	1
7																										1	1	1	1	1	1	1	1	1	1
8																										1	1	1		1	1	1	1	1	1
9																										1	1	1		1	1	1	1	1	1
10																											1	1		1	1	1	1	1	1
11																											1			1	1	1	1	1	1
12																														1	1	1	1	1	1
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25																																			
TOTAL																					2	2	1	2	2	8	10	9	6	15	23	19	16	15	14

APPENDIX 3. Mortality of Alewife in A) Short and Long Loop Experimental Pump Test and B) Controls

Loop System	SHORT LOOP																				LONG LOOP															
Pump Speed (rpm)	436					604					944					1163					436					604					944				
Number of Fish	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1		1				1		1	1	1	1	1	1	1
3	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1	1	1	1								1		1	1	1	1	1	1	
4	1	1	1		1	1	1	1	1	1		1	1	1		1	1	1	1	1								1		1	1	1	1	1	1	
5	1	1	1		1	1	1	1	1	1		1	1	1		1	1	1	1	1								1			1		1			
6	1	1	1		1	1		1	1	1		1	1	1		1	1	1	1	1								1			1		1			
7	1	1	1		1	1						1	1	1			1	1		1								1			1					
8	1	1	1		1	1						1	1	1			1	1		1								1			1					
9	1	1	1		1									1			1	1		1											1					
10	1	1	1		1									1				1													1					
11	1	1	1		1									1																						
12	1	1	1		1									1																						
13	1	1			1																															
14	1	1																																		
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25																																				
TOTAL	17	16	12	2	13	8	5	6	6	6		8	8	12	3	6	9	10	6	8	1	2	1	2		1		5	1	4	8	4	10	4	2

APPENDIX 3 continued..... B) Mortality in Controls

Loop System	SHORT LOOP																				LONG LOOP															
Pump Speed (rpm)	436					604					944					1163					436					604					944				
Number of Fish	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1		1	1			1		1				1	1	1			1	1
2	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1												1	1				1	1
3	1	1	1	1	1	1	1	1	1	1	1		1	1	1		1												1	1				1	1
4	1	1	1	1		1	1	1	1		1																		1					1	1
5	1	1	1	1		1	1	1	1																				1					1	
6	1	1	1	1		1	1	1	1																				1						
7	1		1	1		1	1	1	1																				1						
8	1		1			1	1		1																										
9	1		1				1		1																										
10	1		1				1		1																										
11	1		1				1		1																										
12	1								1																										
13	1								1																										
14	1								1																										
15	1								1																										
16	1								1																										
17	1								1																										
18	1																																		
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24																																			
25																																			
TOTAL	18	6	11	7	3	8	11	7	17	3	4		3	3	3	2	3		1	1			1		1			6	2	1			4	3

APPENDIX 4. Mortality of Yellow Perch in A) Short and Long Loop Experimental Pump Test and B) Controls

Loop System	SHORT LOOP																				LONG LOOP															
Pump Speed (rpm)	436					604					944					1163					436					604					944				
Number of Fish	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1					1	1	1		1		1	1		1	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1
2							1		1		1			1	1	1	1	1		1					1	1				1	1	1	1		1
3															1		1	1		1						1				1	1	1	1		1
4																	1													1	1	1	1		1
5																	1													1	1	1	1		1
6																	1													1	1	1	1		1
7																														1	1	1			1
8																														1		1			1
9																														1		1			1
10																																1			1
11																																1			
12																																1			
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23																																			
24																																			
25																																			
TOTAL					1	1	2		2		2	1		2	3	2	6	3	1	2		1		1	2	3	1	1	1	9	7	12	6	1	10

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APPENDIX 4. continued..... B) Mortality in Controls

Loop System	SHORT LOOP																				LONG LOOP														
Pump Speed (rpm)	436					604					944					1163					436					604					944				
Number of Fish	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1				1	1	1			1	1		1	1	1	1	1	1	1		1		1				1	1	1	1		1	1	1		
2				1		1							1			1						1				1			1			1	1		
3						1																1				1			1			1	1		
4																						1							1			1	1		
5																						1							1			1	1		
6																						1										1			
7																						1										1			
8																						1										1			
9																																1			
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25																																			
TOTAL				2	1	3			1	1		1	2	1	1	2	1	1		1		8				3	1	1	5		1	9	4		

APPENDIX 5. Mortality of White Sucker in the Long Loop Experimental Pump Test

Loop System	SHORT LOOP																				LONG LOOP															
Pump Speed (rpm)	436					604					944					1163					436					604					944				
Number of Fish	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1																															0				
2																															0				
3																															0				
4																															0				
5																															0				
6																															0				
7																															0				
8																															0				
9																															0				
10																															0				
11																															0				
12																															0				
13						-------			N	O		M	O	R	T	A	L	I	T	Y	-------										0				
14																															0				
15																															0				
16																															0				
17																															0				
18																															0				
19																															0				
20																															0				
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22																																			
23																																			
24																																			
25																																			
TOTAL																															0				

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APPENDIX 6. Mortality of Brown Bullheads in the Long Loop Experimental Pump Test

Loop System	SHORT LOOP																				LONG LOOP															
Pump Speed (rpm)	436					604					944					1163					436					604					944				
Number of Fish	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1																															0				
2																															0				
3																															0				
4																															0				
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11																															0				
12																															0				
13						---------- N O					M O R T A L I T Y									----------										0				
14																															0				
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17																															0				
18																																			
19																																			
20																																			
21																																			
22																																			
23																																			
24																																			
25																																			
TOTAL																															0				

POOR

QUALITY

ORIGINAL